Layer 1: Physical Layer

Overview

- Defines physical transmission of data (raw bits over media).
- Involves cables, wireless signals, and device interfaces.
- Standardized primarily by the IEEE 802 group.

Media

- Copper (twisted-pair, coaxial)
- Fiber-optic (short-to-long distances, high capacity)
- Wireless/Radio (varies by IEEE standard and strength)

Transmission Types

- Raw binary transmission: Serial stream of 1s and 0s
- Analog transmission: Used for long-distance communication

Digital Line Encoding

- Unipolar: Positive voltage = "1"
- Polar: Uses positive and negative voltages to represent bits
    - NRZ (Non-Return to Zero): Positive = 1, Negative = 0
    - NRZ-I (Inverted NRZ): Voltage change = 1, No change = 0
- Manchester Encoding (IEEE 802.3):
    - Variation of NRZ
    - Plays a major role in network throughput

Physical Layer Devices

- Repeaters:
    - Amplify and clean digital signals
    - Extend transmission distance
    - Copper: up to 100m; Fiber: 2–60+ km; Wireless: varies
- Hubs:
    - Multi-port repeaters
    - No processing—just repeats signals
    - Rarely used today

Physical Standards (IEEE 802)

- 802.3 (Ethernet): Copper & Fiber transmission standards
    - Example: 1000BaseT = Gigabit Ethernet over copper twisted pair
- 802.11 (Wi-Fi): Wireless LAN standards

Copper Media

- Types:
  - Coaxial: RG-59, RG-6 (long distance)
  - Twisted-Pair: CAT-3, CAT-5, CAT-6, CAT-7, etc. (LAN)
- Issues:
  - EMI (Electromagnetic Interference): Unwanted signals affecting transmission
  - Cross-talk: Interference between parallel cable signals

Mitigation Techniques

- Shielding: Blocks outside interference
- Twisting: Reduces cross-talk between pairs
- Common-Mode Rejection (CMR): Logical filtering to eliminate noise

Twisted-Pair Variants

- UTP (Unshielded Twisted Pair):
  - No or partial shielding
  - Cheap, easy to install, but vulnerable to EMI
- STP (Shielded Twisted Pair):
  - Shielded conductors
  - Expensive, less flexible, harder to install, but EMI-resistant

Power over Ethernet (PoE)

- 802.3af (PoE):
  - 12.95 W, uses 2 pairs (Blue & Brown)
- 802.3at (PoE+):
  - 25.5 W, uses 2 or 4 pairs depending on device
- Common Uses:
  - VoIP phones
  - Security cameras
  - Wireless access points
  - Physical access controls
  - Fire/safety devices
  - IoT devices

Key Takeaways

- Media types: Copper, Fiber, Wireless
- Transmission: Binary, Analog, Line Encoding
- Devices: Repeaters, Hubs
- Standards: IEEE 802.3 (Ethernet), IEEE 802.11 (Wireless)
- Copper Media: UTP vs STP, EMI prevention, PoE support
- Distances:

- Copper: 100m
- Fiber: 2–60+ km